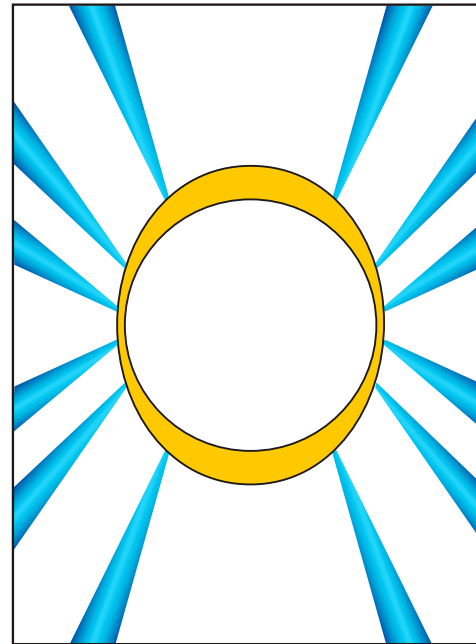
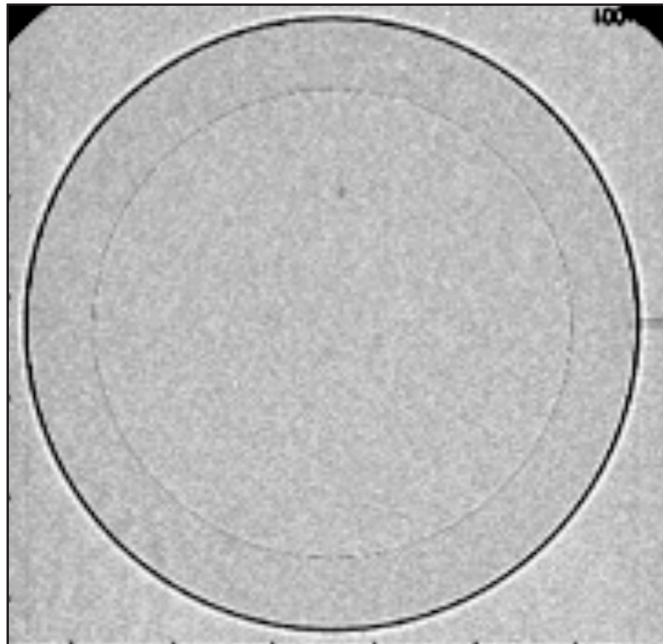


# The NIF Polar-Drive Cryogenic Target



**D. R. Harding and M. D. Wittman**  
**University of Rochester**  
**Laboratory for Laser Energetics**

**20th Target Fabrication Meeting**  
**Santa Fe, NM**  
**20–24 May 2012**

## Summary

**We have a viable polar-drive fill-tube target, a concept for the layering sphere that can meet the space constraints of the NIF, and we are adding infrastructure for tritium operations**

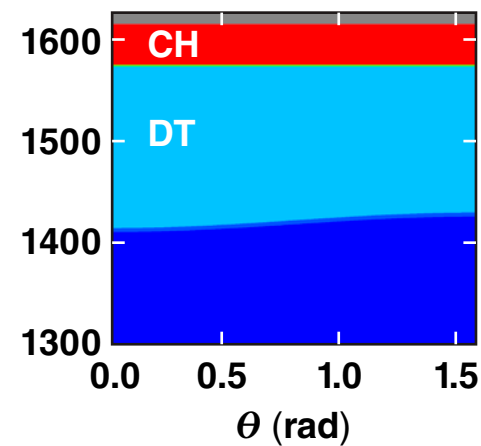
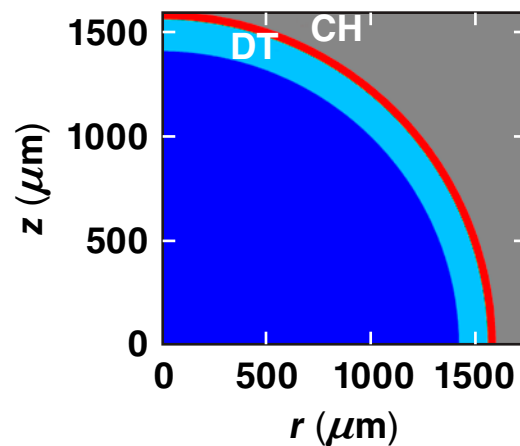
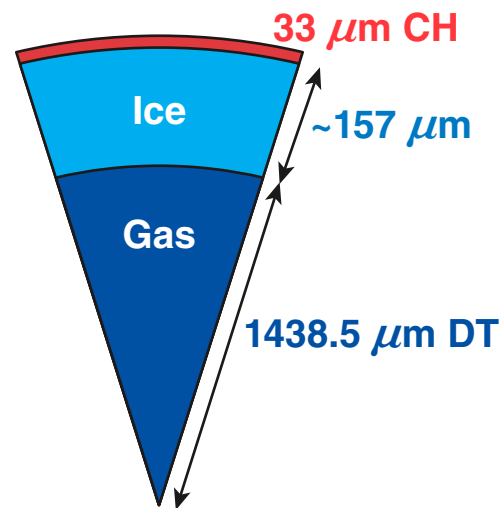


- **Planning for cryogenic polar-drive experiments on the NIF in FY17**
- **Tested different fill-tube configurations and have demonstrated a viable structure**
- **Demonstrated an operational cryogenic system that must be integrated with the NIF-ITIC**
  - **modifying the system for DT operations—ready January 2013**
- **In the process of miniaturizing the target's thermal environment to allow for easier integration with the existing NIF-ITIC**
- **We have final engineering drawings for the tritium containment and handling equipment**

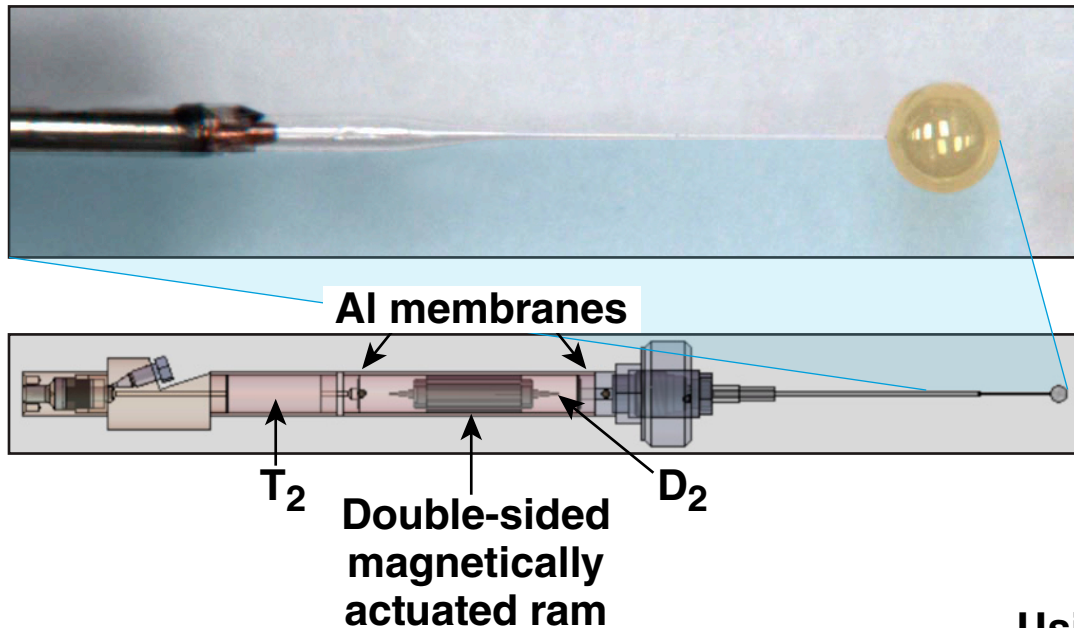
# The baseline NIF polar-drive target design uses ice-layer shimming



“Shimmed” target  
2-D gain = 32



# The fragile fill-tube assembly strongly influences the design of the Cryogenic System



Fill-tube diameter =  $30\ \mu\text{m}$

Fuel thickness =  $350\ \mu\text{m}$

Reservoir volume = 3.4 ml

Fill pressure = 72 psia

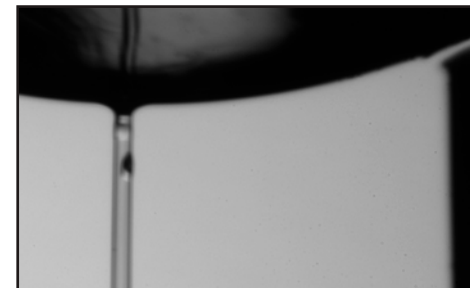
Fuel remaining in reservoir at 18.7 K = 38% of total

Fuel inventory = 21 Ci

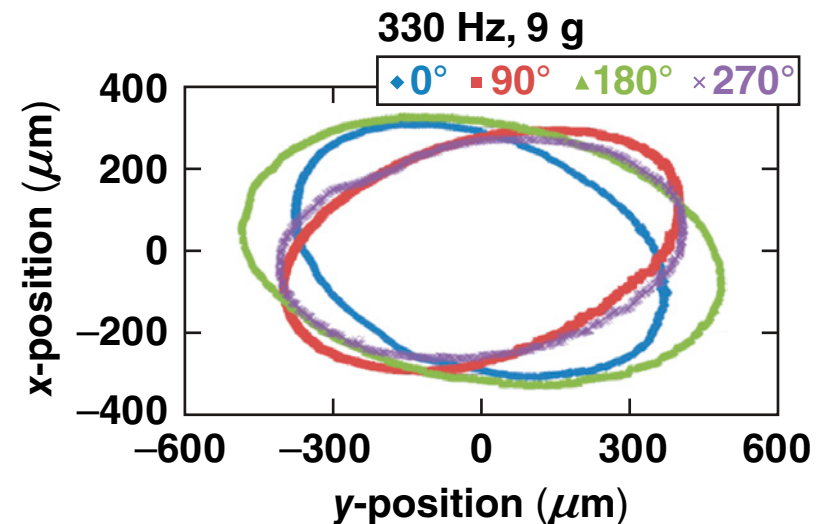
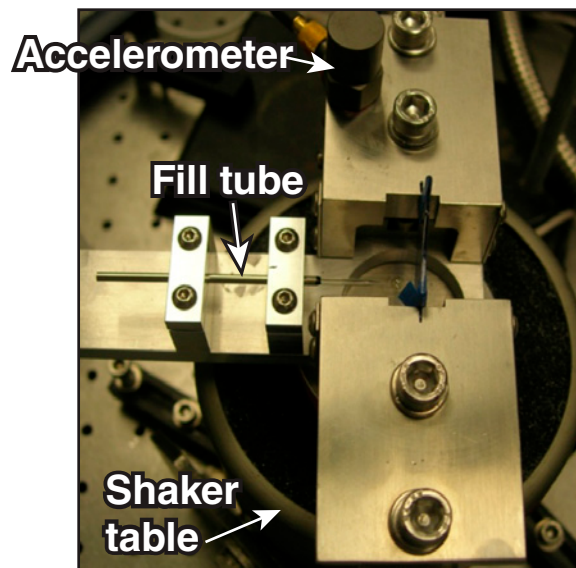
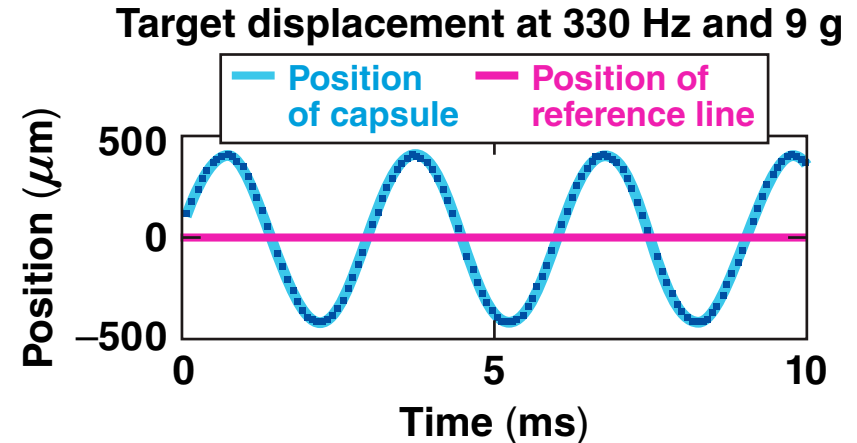
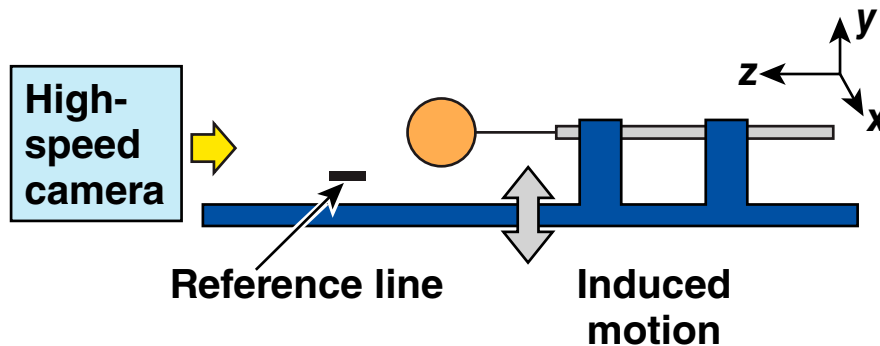
## Performance statistics:

2 of 13 targets tested in the Cryogenic Test System over two years did not leak

Using an additional fiber to support the target is ineffective

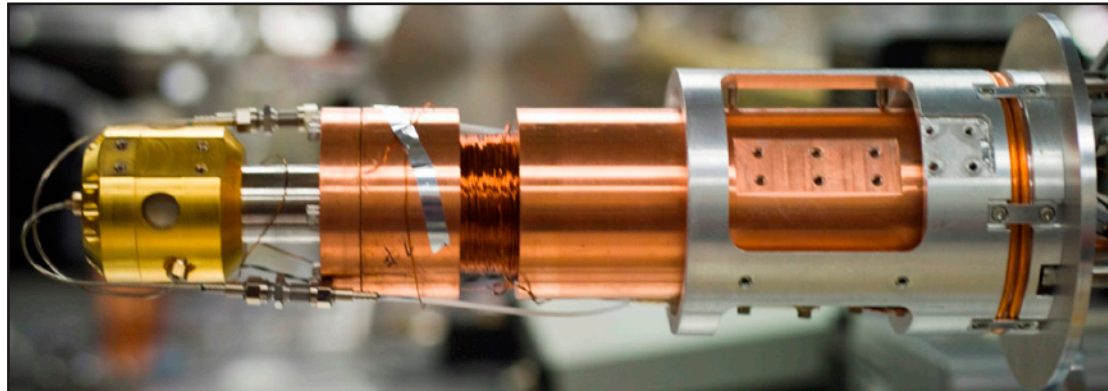
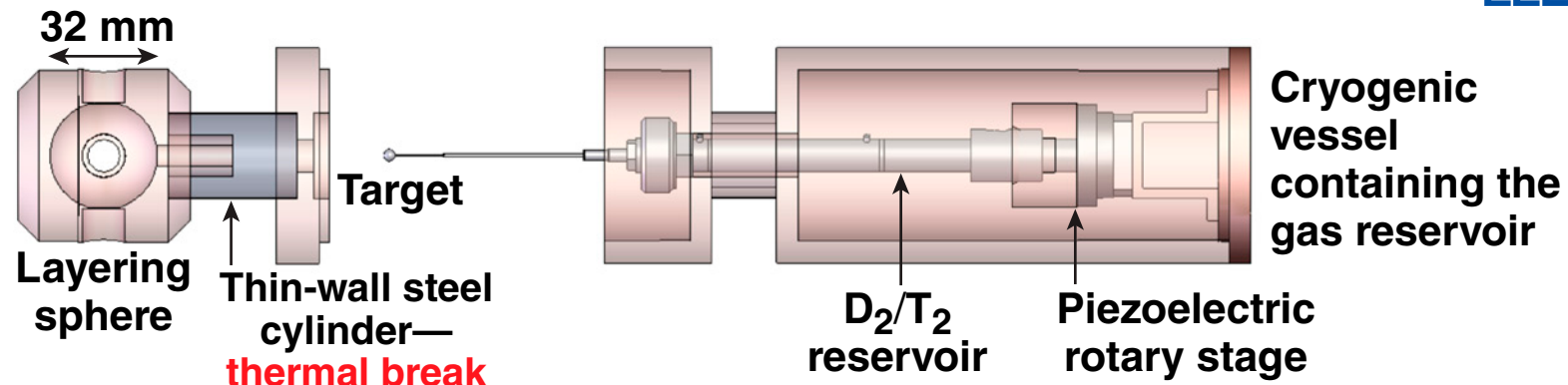


# General Atomics is working to characterize the performance of the fill-tube assembly and to improve its robustness



- No target survived 12-g impulses (3 tests)

# A first generation design of the thermal envelope that surrounds the target is functional

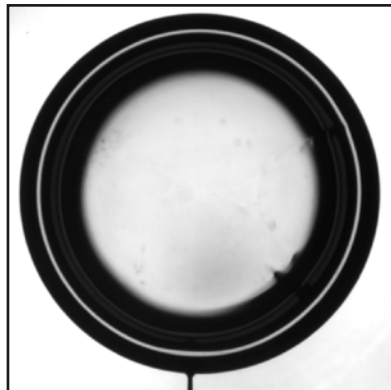


- This design provided performance metrics for future improvements—addressed by LLE's Target Group
- The surrounding mechanics and interfaces with the NIF-ITIC will be addressed by LLE's and LLNL's engineering groups

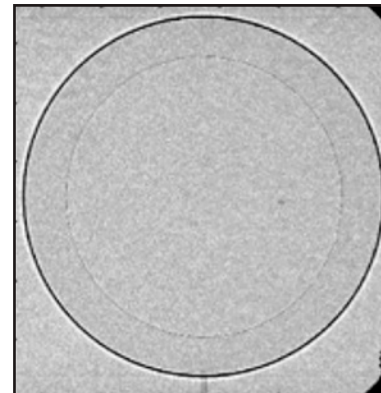
# Demonstrated control of the ice-layer thickness to $\pm 3 \mu\text{m}$ and the ability to form a stable $\text{D}_2$ ice layer—sufficient to progress to DT operations



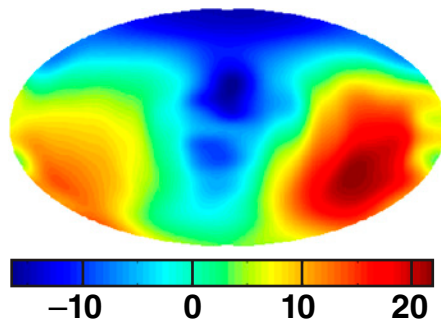
- 343- $\mu\text{m}$   $\text{D}_2$  ice layer inside a 3.01-mm-diam capsule with 20- $\mu\text{m}$  wall and a 30- $\mu\text{m}$ -diam fill tube



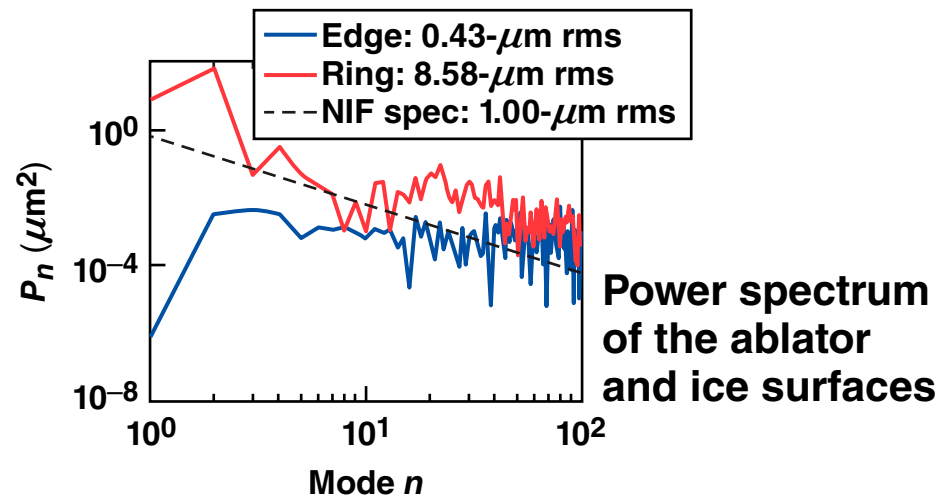
Shadowgram



X-ray phase-contrast image

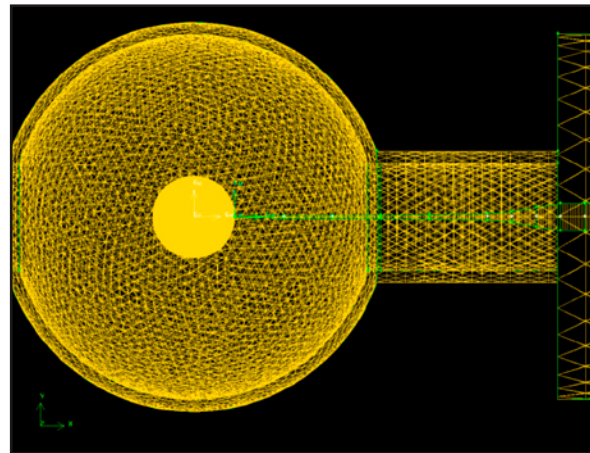
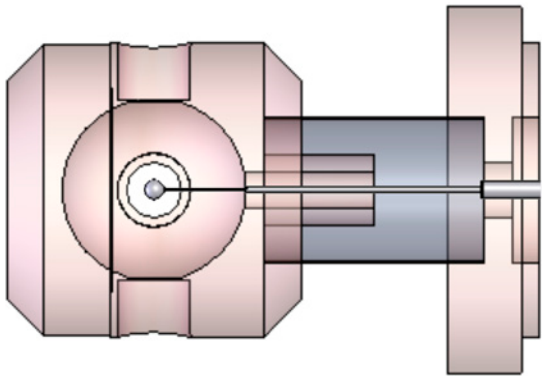


3-D Aitoff projection of the ice roughness ( $\mu\text{m}$ )

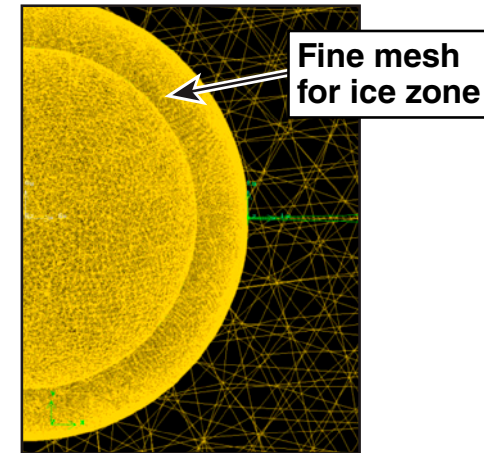




# A thermal model of the target, fill tube, and layering sphere is used to refine the design of the cryogenic equipment



Layering sphere/target



Target/ice layer

## Mesh Parameters

Minimum volume:  $18 \mu\text{m}^3$

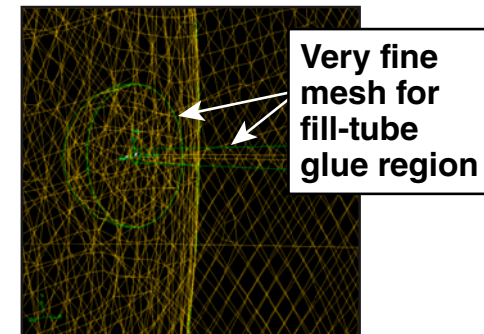
Maximum volume:  $0.8 \text{ mm}^3$

Minimum surface area:  $10 \mu\text{m}^2$

Maximum surface area:  $6 \text{ mm}^2$

$18 \times 10^6$  cells

$36 \times 10^6$  faces



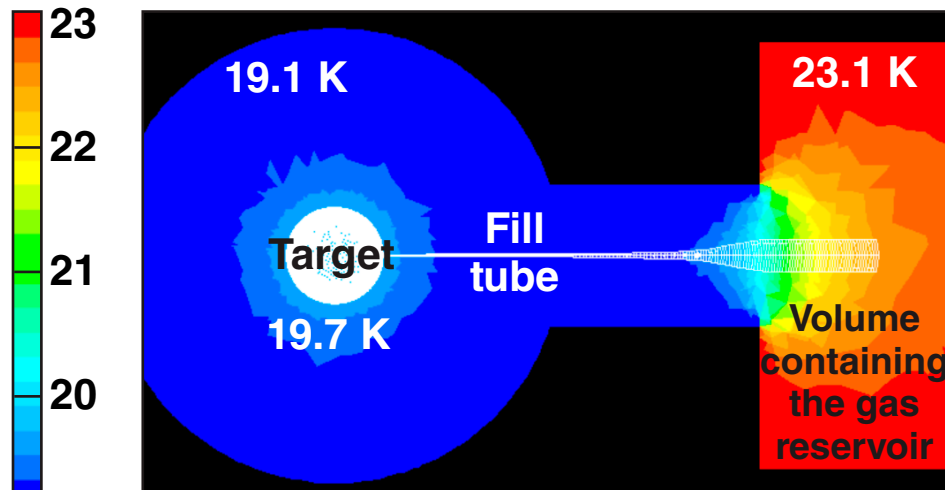
Fill-tube/glue



# A thermal model of the target, fill tube, and layering sphere is used to refine the design of the cryogenic equipment



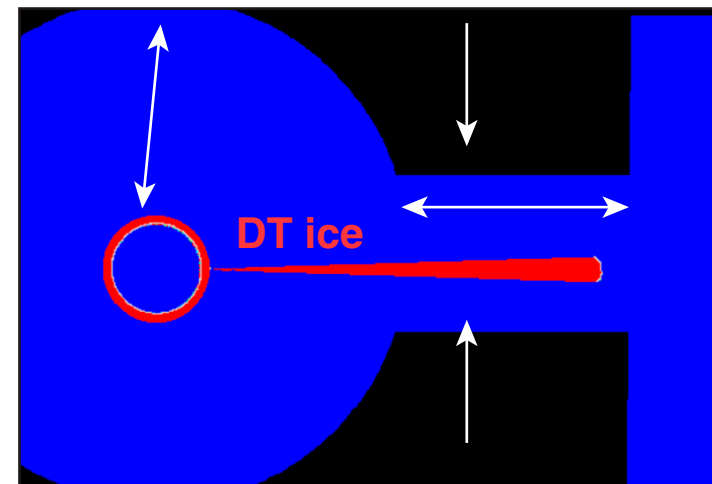
Temperature boundary conditions  
taken from measurements  
in the D<sub>2</sub> experiments



3.3-mm-diam capsule and 16-mm  
inner-diameter (i.d.) layering sphere

Design variables

- layering-sphere inner diameter
- entrance hole length
- entrance hole diameter



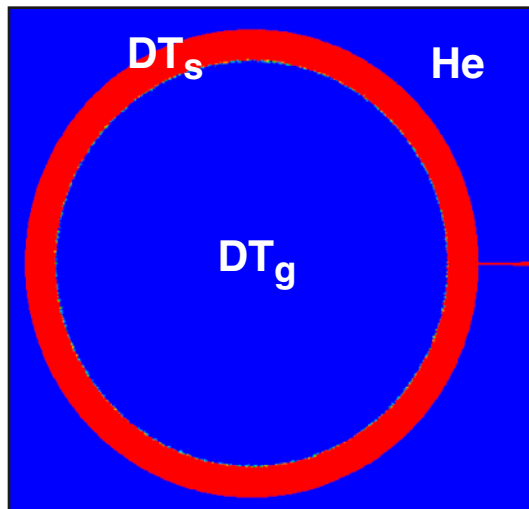
Calculation parameters:

- Time step: 0.2 s
- Convergence (energy residual):  $1 \times 10^{-12}$
- Run time: ~4 min/iteration—7 to 10 days on an 8-processor, 24-GB system

# Calculations predict that a layering sphere with a diam (16 mm) that is one-half of the current system will be acceptable

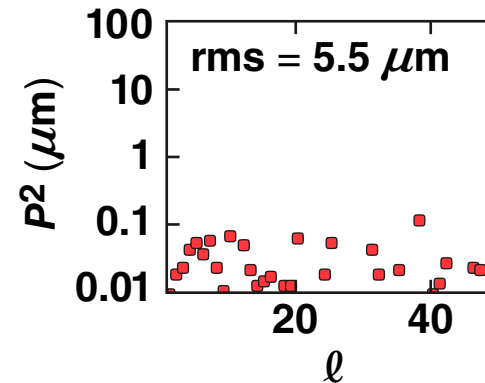


Calculated ice distribution  
for a 2-D slice through the target  
217- $\mu\text{m}$  thick ice layer

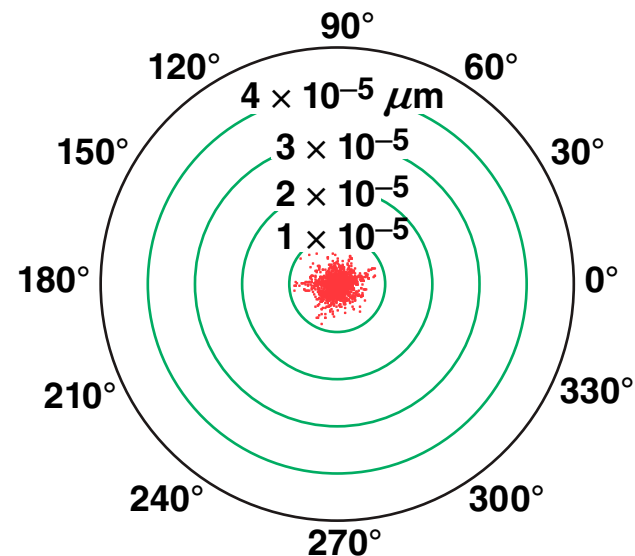


- Calculated rms roughness affected by the mesh resolution and interpolation within each voxel at the ice/gas interface
- No effect due to the fill tube (30- $\mu\text{m}$  o.d., 10- $\mu\text{m}$  i.d.)

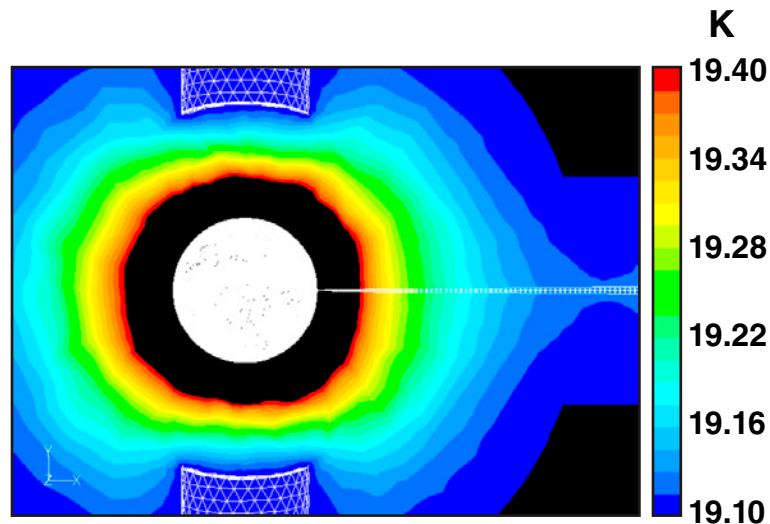
Calculated 2-D power spectrum



Polar plot showing the azimuthal variation  
of the ice surface from a circle

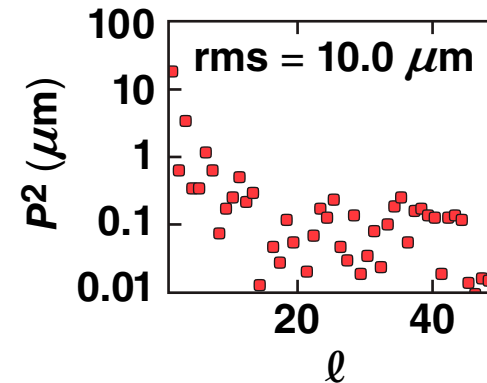


# Re-entrant cylinders at the north and south poles of the layering sphere perturb the ice layer by an amount that can be controlled

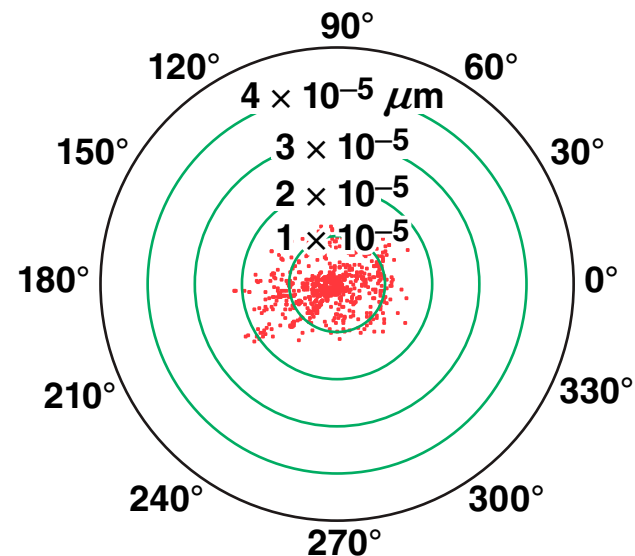


Experiments and additional thermal modeling with a finer mesh are planned. Sensitivity of the ice distribution to the target's position and the gas pressure need to be determined.

Calculated 2-D power spectrum

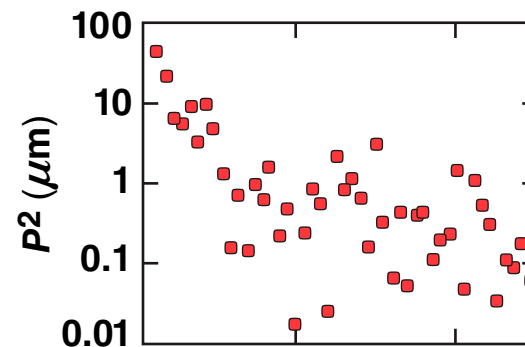
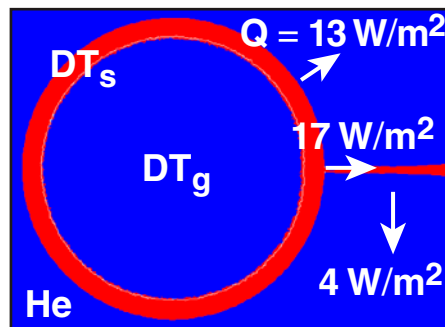


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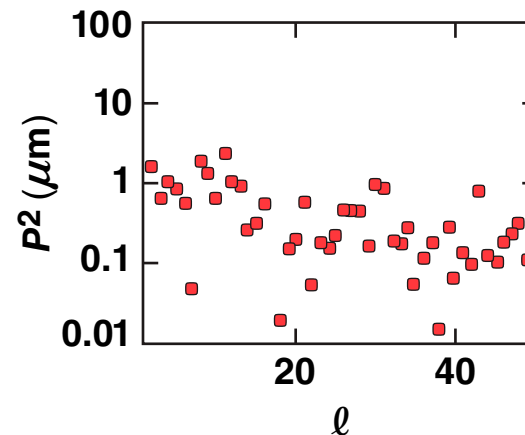
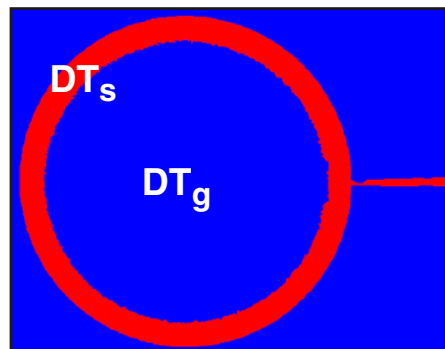


# Increasing the thickness of the fill tube to make it more stable and robust perturbs the ice layer; heating the fill tube offsets the effect

Effect of a 200- $\mu\text{m}$  o.d. fill tube on the ice layer (16.5- $\mu\text{m}$  rms)



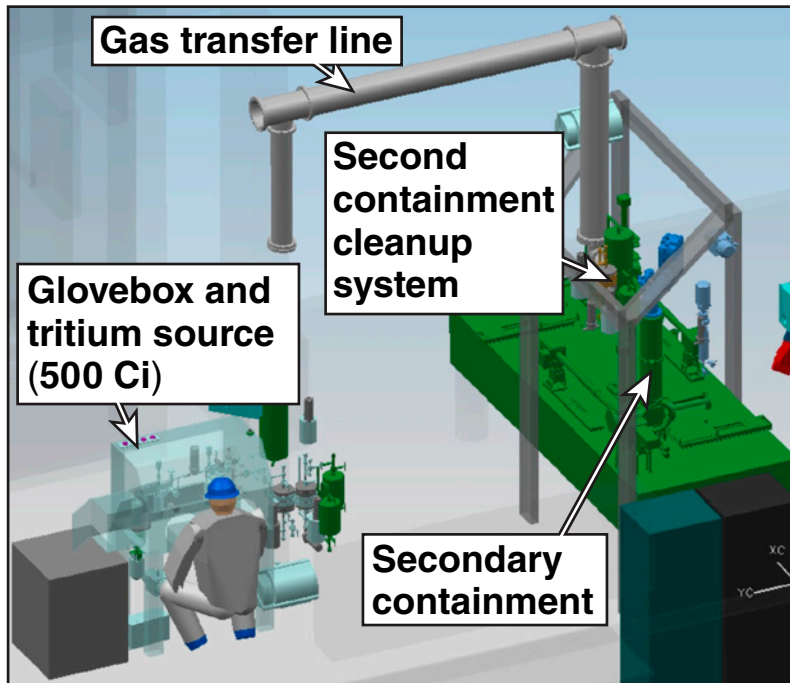
5  $\mu\text{W}$  coupled into the fill tube offsets the added heat flux



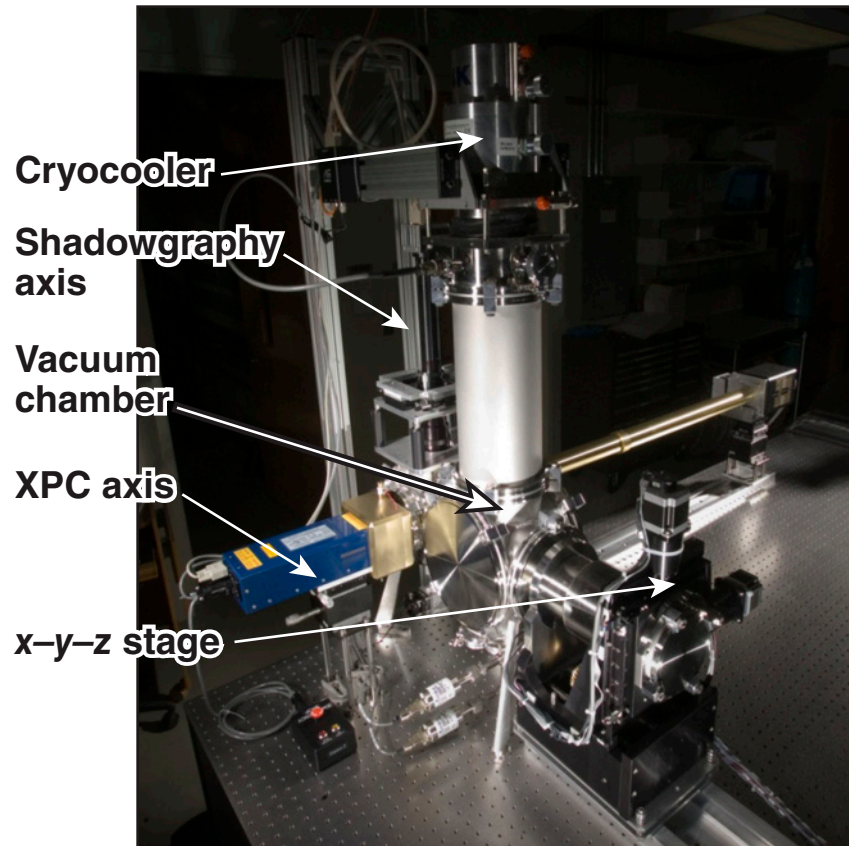
While a larger fill tube will affect the implosion performance, the effect of the fill tube on the ice layer can be mitigated.

# A tritium source, clean-up systems, and containment are being added to the existing cryogenic equipment to qualify the layering-sphere design

## Tritium, clean-up, and containment equipment



## Surrogate NIF-PD-ITIC Equipment



## Summary/Conclusions

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